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DRYING KIEFFER PEARS AND THE USE OF THE DRIED PRODUCT

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INTRODUCTION

For some time work concerned with the possibilities of improving the quality of the Kieffer pear, so that it may be more completely utilized than has been the case in the past, has been in progress in this laboratory. Lutz, Culpepper, Moon, and Myers (13)¹ have shown that the temperature at which the material is ripened has a very striking influence upon the quality of the fruit when canned as well as when used fresh. It has been found that when the fruit is harvested at the proper time and ripened at 60° F. its quality is much better than when ripened at any higher temperature. It is evident that many of the objectionable characteristics usually present in the fruit are overcome in this way. Likewise it has been shown by Moon and Culpepper (18) that if properly ripened fruit is used a fair quality of preserve may be made, provided that the proper proportions of fruit and sugar are used and that the mixture is boiled to the proper temperature at the finish. It was considered desirable to carry out similar tests dealing with the drying of the material.

In beginning the tests, it seemed necessary to obtain first a thorough understanding of the factors that influence the rate of drying, and a rather comprehensive study of these has consequently been made. The results of the work done in this connection have been stated in another report (10). A considerable number of other

¹ Italic numbers in parentheses refer to Literature Cited, p. 23.

tests dealing with the drying of the material and the use of the dried product have been made.

There seem to be no records describing in detail attempts to dry the Kieffer pear. The drying of Bartlett pears is described rather fully by Cruess and Christie (8). They are apparently not dried to any extent outside of California, and the principal method used is sun-drying.

PURPOSE OF THE WORK

A number of tests have been made to determine the effects of different methods of preparation upon the quality of the dried product and the differences that may be expected in products made from ripened and unripened fruit. The properties of the dried material have been studied, and its behavior in storage in atmospheres of different humidities has been determined. Tests dealing with the refreshing of the fruit and the preparation of the material for the table have also been carried out. It is the purpose herein to report the results of these tests.

MATERIAL AND METHODS

The fruit for these tests was grown at the National Agricultural Research Center, Beltsville, Md., during the season of 1934. An ample quantity of material was harvested and a large portion of it was ripened in a room held at a constant temperature of 15.5° C. (60° F.). A quantity of the unripened fruit was dried immediately, but a large amount was placed in storage at 0° C. (32° F.) until the experimental tests could be carried out. The material was fairly typical of Kieffer pears in general.

The material was dried in a small steam-heated dryer of the stack type, modified to permit the making of tests under widely different conditions, a detailed description of which has been given in another report (10). In most of these tests the temperature of the drying air as it entered the dryer was approximately 50° to 55° C., and it had a relative humidity of 9.2 percent. When the dryer was loaded the air velocity varied somewhat on different trays, ranging from a fraction of a mile per hour to 3 miles per hour. Its relative humidity when discharged was around 60 percent and the temperature had fallen to 35° C. Of course, there was not a very efficient use of the heat supplied, but the data are given to show that excellent drying conditions existed in the dryer. However, in many other tests small lots were dried under widely varying conditions.

PEELING AND PREPARATION OF THE FRUIT FOR DRYING

In considering the procedure in drying or dehydrating the fruit the question at once arises: Should the material be peeled? Or, of what significance is the difference in the quality of the peeled and unpeeled product after drying? In considering the quality of the two products, it is well to bear in mind the losses to be expected from peeling and coring. To get some idea of the losses in peeling, 68 fruits, half of them ripened and half unripened, were weighed before and after peeling and before and after coring, and the difference was calculated as percentage loss. The fruit varied widely in size and shape. The peeling and coring was done by hand, using the customary guarded knife in peeling and the usual looped knife for removing the cores.

In figure 1 the percentages of total losses and the losses in peeling alone have been plotted against the size of the fruit. It is readily observed that there was considerable variation in individual fruits of approximately the same size. In fruits weighing between 195 and 200 g the extreme difference in total loss was from a little below 20 percent to a little more than 30 percent. This was apparently due to differences in the smoothness of the surface and in the size and shape of the core, as well as to errors due to inability to core the fruits in exactly the same manner. However, there is a distinct tendency for the total losses to be greater in the smaller fruits. This difference between the large and small fruits is not quite so marked as might have been expected from their great variance in size. It is evident that for fruit of average size (160 to 200 g) a loss of at least 25 percent may

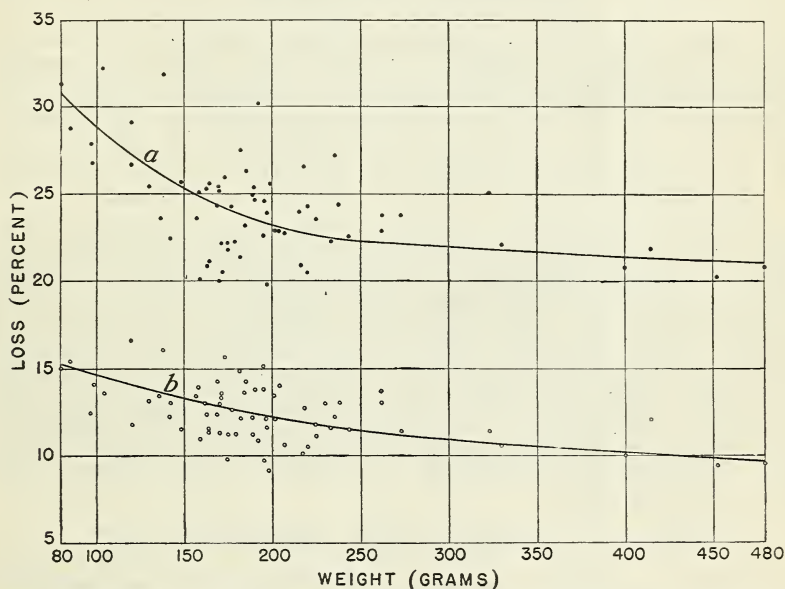


FIGURE 1.—Relation of size of the Kieffer pear to the weight loss in peeling and coring: *a*, Total loss; *b*, loss after peeling only.

be expected in peeling and coring. Except for very small fruits, the difference in size did not make a great difference in the percentage loss.

In the losses from peeling alone, the differences in the large and small fruits are even less marked than the total losses. For fruits of average size a loss of about 13 percent may be expected. These results apply only to fruit peeled and cored with the regular guarded knife and coring spoon generally used in peeling the fruit in commercial practice. If an ordinary paring knife is used the losses may be very much greater than this. The fruit cannot be effectively or efficiently prepared by hand without the use of these instruments; if it has blemishes of any kind that must be removed the losses will be correspondingly greater.

The losses were a little greater in peeling and coring the unripened fruit than the ripened. This was apparently due to the hard tissues of the unripened fruit that made it more difficult to cut to a uniform

depth. A pear peeling, splitting, and coring machine has been invented (17) which greatly reduces hand labor, and the finished product is much more uniform than with hand peeling.

In these tests the differences in quality of the finished product of the peeled and unpeeled fruit were so marked that it seems inadvisable to attempt to dry the material without peeling and coring. The unpeeled fruit was less attractive in appearance and less palatable when cooked because of the presence of the skins and stone cells. The time necessary properly to sulphur the material (p. 5) was very greatly increased and the rate of drying was much slower. The removal of the core is particularly important in determining quality, since the greater part of the stone cells are located in and near the core.

SUBDIVIDING THE FRUIT

The effect upon the rate of drying of slicing the fruit into segments of different size has been considered elsewhere (10). However, there are factors other than rate of drying to be considered. These tests indicate that the material may be dried satisfactorily when sliced in nearly any manner, under the proper conditions. As will be shown later, the refreshing of the material, like the rate of drying, is hastened by subdividing the fruit. However, these tests indicate that the very finely sliced material is not so convenient to prepare for the table or so attractive when prepared as fruit sliced into larger pieces. There is a greater tendency for the finely sliced material to be completely disintegrated so that the original shape of the pieces is lost; on the other hand, the dried halves are sometimes less conveniently prepared for the table than fruit sliced to four or eight segments. From these tests the writers have concluded that, all things being considered, division of fruit of average size into eight segments is about the best procedure. Segments of this size dry rapidly, are easily refreshed, are convenient to prepare for the table, and are attractive when served.

RIPENED COMPARED WITH UNRIPENED FRUIT

In order to study the characteristics of the ripened and unripened fruit, a large quantity of material was picked and divided into two portions, one of which was ripened at 15.5° C. (60° F.) prior to drying, and the other was dried without any ripening treatment. A portion of the unripened material was dried immediately after harvesting, but a quantity was put in storage at 0° C. (32° F.) until the ripened material was ready for use.

Both lots were then peeled, cored, exposed to the fumes of sulphur for 4 hours (p. 5), and dried under identical conditions. The fruit that had been ripened, tested 3.1 pounds with the Magness pressure tester (15); the unripened tested 13 pounds. There was a very marked difference in appearance between the ripened and unripened material. There was little or no browning in either case, as the sulphuring appeared to be ample. The unripened material took on a grayish or white appearance during drying; the ripened was of a pale yellow or amber color. As drying proceeded, the differences in appearance became more pronounced, so that the unripened appeared opaque with a whitish or grayish color and seemed starchy and coarse.

At the finish the ripened material appeared somewhat translucent and yellow or amber colored, and was somewhat suggestive in its appearance of certain candied fruits. When dried to 15-percent moisture the ripened fruit was soft and pliable, while the unripened was harder and less flexible. The unripened material held its shape more nearly perfectly than the ripened, the latter appearing to have undergone more shrinkage, but, as will be shown later, this was because of the manner of shrinking and not the volume.

In order to compare the quality of the two lots of material after refreshing, a quantity of each, sliced into eight segments, was soaked overnight in enough water to make its moisture content about 85 percent. The material did not absorb quite all the water. The following morning the two lots were brought approximately to a boil and allowed to simmer slowly for 10 minutes with occasional stirring. The unripened material held its shape much better than the ripened, but was tough, woody, and lacked flavor; the ripened was tender, attractive in appearance, and seemed less gritty than the unripened. It was apparent that the unripened material was entirely unsatisfactory, while the ripened material was a fair product approaching the quality of the best dried Bartlett pears.

TREATING THE FRUIT WITH SULPHUR DIOXIDE

The pear, like most fruits, rapidly turns brown when the sliced material is exposed to the air. There are several methods of preventing or minimizing this change, the most effective being the exposure of the material to the fumes of burning sulphur, or sulphur dioxide. This was the only method used in these tests. One lot of material consisting of peeled halves and fruit peeled and sliced into eight radial segments was dried without any treatment; another lot was exposed to the fumes of sulphur dioxide for 2 hours; a third lot, consisting of peeled and unpeeled halves and fruit peeled and sliced into eight radial segments, was exposed to the sulphur dioxide for 4 hours; and a fourth lot, of peeled and unpeeled halves, was exposed to the fumes for 7½ hours. These tests indicate that 2 hours' sulphuring is decidedly inadequate for fruit sliced into halves and scarcely sufficient for fruit sliced into eight segments; 4 hours' sulphuring seemed to be entirely sufficient for the peeled fruit, but was still inadequate for the unpeeled fruit. The unpeeled fruit sulphured for 7½ hours was still insufficiently sulphured, and it was concluded that it would require 12 or more hours' exposure to attain the desired color.

The difference in the color of the sulphured and unsulphured fruit was quite marked. The unsulphured fruit was quite brown in the case of the halves, but somewhat less so in the fruit sliced into eight segments. When both products were tasted shortly after drying, the flavor of the unsulphured material was much superior to that of the sulphured fruit. After refreshing and cooking, the difference is less marked, but the flavor is still decidedly more pleasing in the unsulphured material. However, unless the storage conditions are very good the unsulphured product gradually loses much of its natural flavor, with the result that after 9 to 12 months under ordinary storage conditions the sulphured material is equal or superior in flavor to the unsulphured fruit.

SHRINKAGE OF THE MATERIAL

A visual inspection of the dried pieces of fruit revealed that the surface did not split or crack appreciably during drying, which indicated that the fruit must shrink in all dimensions. In order to ascertain the amount of shrinkage, an eighth section was taken from each of four ripened fruits that had been peeled and cored. Sections were weighed, their volume was measured by immersing in ether, and the specific gravity calculated. The sections were then dried at 60° C. in a current of air having a velocity of 4.9 miles per hour and a relative humidity of 4.2 percent. The pieces were again weighed and their volume measured in the same way. The test was repeated six times and the results averaged. The fresh material at the beginning had a specific gravity of 1.042 and after drying the specific gravity was 1.193. The loss in weight was 84.9 percent of the fresh weight and the loss in volume 88.1 percent of the original volume. The percentage loss in volume was a little more than the percentage loss in weight, which resulted in the increase in the specific gravity of the dried product. The volume of water lost was practically equal to the decrease in the volume of the fruit.

It may be inferred that there is very little air in the fresh fruit and very little in the dried material, so that little if any is taken up or driven out of the material in drying. A quantity of ripened fruit that lost 84.9 g in weight lost 84.48 cc in volume. A test was carried out upon the unripened material in exactly the same way with practically the same result. Although the ripened fruit appeared to shrink more than the unripened, the actual shrinkage was the same in both cases. When drying is done at a temperature of 60° C. there is a tendency for the ripened material to flatten out somewhat as a result of the action of the heat and gravity. The unripened pieces do not flatten out in this way. The apparent difference in the shrinkage is consequently due to distortion and flattening of the form of the soft ripened fruit, which increases as higher temperatures are used, so that it may become quite pronounced at 70°.

COMPOSITION OF THE KIEFFER PEAR AS RELATED TO THE DRYING PROCEDURE AND QUALITY OF THE DRIED PRODUCT

Many of the qualities of the Kieffer pear as well as those of the products prepared from it are attributable to or related to its chemical composition. The data presented in table 1 and taken from the report of Lutz, Culpepper, Moon, and Myers (13) show that the total sugar content of the Kieffer pear ranges between 6.63 and 7.79 percent with a titratable acidity ranging between 0.175 and 0.229 percent. In various analyses of the Bartlett pear reported by Magness (14), the sugar content of the fruit when ripened after picking at the proper stage ranged between 8 and 10 percent, with titratable acidity ranging from 0.246 to 0.39 percent.

Both the sugar and the acid content of the Bartlett pear are consequently somewhat higher than those of the Kieffer, but the ratio of acid to sugar does not differ greatly in the two fruits. Judging from its composition as compared with the Bartlett it appears that the Kieffer pear should yield a fair product when dried.

TABLE 1.—*Firmness and composition of Kieffer pears at time of harvesting (Oct. 25) and after 20 days in storage at various temperatures expressed on the fresh-weight basis*

Temperature of storage (° F.)	Pressure test	Solids soluble in al- cohol	Solids insolu- ble in alcohol	Total solids	Total sugar	Titrat- able acidity	Total astrin- gency	Proto- pectin	Ratio of soluble pectins to pro- topectin
	Pounds	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
No storage.....	12. 0	12. 92	3. 23	16. 15	6. 90	0. 208	0. 067	0. 44	0. 65
40.....	11. 1	12. 60	3. 38	15. 98	7. 05	. 229	. 096	. 41	. 77
50.....	6. 5	11. 92	3. 29	15. 21	6. 69	. 218	. 095	. 31	1. 33
60.....	4. 0	11. 56	3. 23	14. 79	7. 74	. 205	. 075	. 20	1. 89
70.....	7. 1	11. 14	3. 50	14. 64	6. 63	. 180	. 087	. 27	1. 15
80.....	10. 6	12. 26	3. 50	15. 76	7. 15	. 202	. 095	. 43	. 73
90.....	11. 2	13. 04	3. 72	16. 76	7. 25	. 225	. 113	. 46	. 62
100.....	13. 0	15. 16	3. 86	19. 02	7. 79	. 175	. 106	. 47	. 78

The dry matter of the Kieffer pear ranges between 14 and 17 percent, which compares favorably with that of the Bartlett pear and with that of many other fruits that are extensively dried. The greater part of the dry matter is sugar and other soluble materials, which should make the dried product easily refreshed and cooked in preparing it for table use. A somewhat greater proportion of the total solids of the Kieffer pear consists of alcohol-insoluble materials, the difference from the Bartlett being due largely to the stone cells which consist chiefly of lignocellulose. Crist and Batjer (4) have studied extensively the stone cells in the Kieffer and other pears. The presence of the stone cells is one of the most objectionable features of the Kieffer pear from the standpoint of the dried product, for they become more apparent during the drying process, especially in the unripened material. The tannin content is as low, or lower, than in most of the fruits that are dried, which makes the difficulties due to discoloration less than in many fruits.

The total pectin content of the Kieffer pear is not high, but there is a considerable increase in the soluble pectin during ripening, which probably accounts for much of the differences in the texture and quality of the products made from the ripened and the unripened fruit.

BEHAVIOR OF THE DRIED PRODUCT WHEN STORED IN ATMOSPHERES OF DIFFERENT HUMIDITY

The extent to which a product is preserved by drying depends upon the deterioration that may occur in storage subsequent to drying, and its value or usefulness depends to a considerable extent upon the physical characteristics of the dried product. One factor in the storage conditions that may be of much importance is the humidity of the air. Gore and Mangels (11) have emphasized this factor in a study of the deterioration of raw-dried vegetables in storage. The influence of different humidities depends upon the physical properties of the material. A number of tests have been made to determine the physical characteristics of the material and its behavior in storage. The method employed was essentially that used by Culpepper and Caldwell (9) in studying the effect of atmospheric humidity on the rate of deterioration of stored evaporated apples.

Material prepared in several different ways was stored in lots in atmospheres containing various percentages of moisture, and the behavior of the material was noted. Small storage chambers were

prepared by placing a graduated series of solutions of sulphuric acid of the proper concentration in large inverted bell jars which were covered with glass plates and made tight by applying stopcock grease or petrolatum to the contact surfaces, and the material was placed in the atmospheres above these sulphuric-acid solutions. Eleven different humidities ranging from approximately 100 percent to practically zero were thus provided. Fruit that had been peeled and sliced into eight segments was used. One lot was ripened and sulphured; another was ripened and unsulphured; a third was unripened and sulphured; and a fourth was unripened and unsulphured. The material was placed in loosely woven muslin bags, and these were then put in the moisture chambers and held in storage at a temperature of 20° to 23° C. for 6 months, when it became necessary to discontinue the test. The material was examined at frequent intervals to note its behavior as to color, flavor, and other characteristics.

The results of the tests as to color and flavor are given in table 2. The numerical values are based upon the personal preferences of the judges, chiefly members of the laboratory where the work was done. A reading of 1 represents the most desirable product; a rating of 10 represents the least desirable or the poorest.

TABLE 2.—*Changes in color and flavor of dried pears when stored at different humidities, the values given being numerical ratings based upon the personal preferences of the judges*

[1 represents the most desirable quality; while a rating of 10 represents the most undesirable, or poorest]

Relative humidity (percent)	Ripened sulphured				Unripened sulphured			
	1-month's storage		6-months' storage		1-month's storage		6-months' storage	
	Color	Flavor	Color	Flavor	Color	Flavor	Color	Flavor
0.....	1	2	1	2	3	5	3	5
4.96.....	1	2	1	2	3	5	3	5
12.89.....	1	2	1	2	3	5	3	5
21.44.....	1	2	1	2	3	5	3	5
33.30.....	1	2	2	3	3	5	3	6
48.84.....	1	2	3	3	3	5	4	6
62.28.....	2	3	7	4	4	5	5	6
70.82.....	3	6	8	5	6	6	8	7
83.27.....	4	6	9	7	8	8	9	9
94.20.....	6	7	10	10	9	9	10	10
100.....	7	7	10	10	9	9	10	10

Relative humidity (percent)	Ripened unsulphured				Unripened unsulphured			
	1-month's storage		6-months' storage		1-month's storage		6-months' storage	
	Color	Flavor	Color	Flavor	Color	Flavor	Color	Flavor
0.....	5	1	5	1	6	4	6	4
4.96.....	5	1	5	1	6	4	6	4
12.89.....	5	1	5	1	6	4	6	4
21.44.....	5	1	5	1	6	4	6	4
33.30.....	5	1	6	2	6	4	7	6
48.84.....	6	1	6	2	7	5	7	6
62.28.....	6	2	8	4	7	7	8	8
70.82.....	7	4	9	6	7	7	9	8
83.27.....	8	5	9	9	8	8	9	9
94.20.....	8	9	10	10	8	9	10	10
100.....	9	9	10	10	9	9	10	10

It is evident that the dried product deteriorated rapidly in atmospheres of high humidity. At the end of 1 month in saturated air the material had become quite brown and greatly altered in flavor. Molds were beginning to develop in the unsulphured lots. The sulphured material was somewhat better preserved than the untreated, but both were quite brown. At the end of 6 months all were quite brown, so that there was not very much difference in the materials treated in different ways. Molds were more in evidence in the unsulphured lots. All lots had strong or abnormal flavor and were considered unusable as food. In a relative humidity of 83.27 percent both color and flavor were considerably better, at 62.28-percent moisture there was a decided improvement, and in the 33.3-percent relative humidity only a very small amount of change could be detected at the end of 6 months. The material stored in air of 48.84-percent relative humidity retained its normal color and flavor remarkably well. No change in color or flavor was noted in the material in perfectly dry air, and it is concluded that the material would remain unchanged indefinitely. While the materials that had been treated and dried in different ways were quite different at the beginning of the storage they all deteriorated in very much the same manner. Molds did not develop on the sulphured material even in the air saturated with moisture during the entire storage period.

It was necessary to discontinue the storage at the end of 6 months, but it was concluded that the major part of the change that might be expected to develop had occurred during this time and that further change would be much less rapid and much less apparent than that which occurred during the first 6 months.

MOISTURE-ABSORBING CAPACITY OF THE DRIED PRODUCT

For the tests upon the moisture-absorbing capacity of the dried material, two lots of fruit—one ripened, the other unripened—were peeled, each fruit sliced into eight segments, and dried without sulphuring or any other treatment at a temperature of 50° C. Following drying, the material was placed in a vacuum oven (at 28 pounds negative pressure) over calcium oxide and dried for 48 hours longer at 70°. From this material lots were weighed out, placed in loosely woven muslin bags in the moisture chambers already described (p. 8), and kept in storage at a temperature between 20° and 23° for 6 months, at which time equilibrium had practically been established. Several times during the period they were weighed and the moisture content of the material calculated. The water absorbed was also calculated as percentage of the original dry weight of the material. Table 3 shows the relative humidities present in the various chambers and the concentration of the sulphuric acid solutions used to produce them; it also gives the results of the test in percentage of the water absorbed and the moisture content of the material. In the high humidities the result is given of the last weighing made before mold growth vitiated the result. The moisture content of each lot of material may be considered as the equilibrium moisture or the moisture content at which the material has reached equilibrium with the air of the chamber in which it was stored.

TABLE 3.—Percentages of water absorbed and the moisture content of peeled, unsulphured Kieffer pears dried with and without previous ripening when stored in atmospheres of different humidities

Concentration of H ₂ SO ₄ (percent)	Relative humidity of storage chamber	Unripened		Ripened	
		Water absorbed	Moisture	Water absorbed	Moisture
	Percent	Percent	Percent	Percent	Percent
0.....	100	65.1	39.4	68.1	40.50
24.26.....	94.2	54.8	35.4	55.5	35.70
33.10.....	83.27	33.2	24.94	34.0	25.40
37.69.....	70.82	24.8	19.88	24.9	19.96
43.75.....	62.28	18.1	15.30	17.9	15.19
52.13.....	48.84	11.1	9.89	10.3	9.32
57.65.....	33.30	5.30	5.01	3.70	3.57
64.47.....	21.44	2.90	2.8	.46	.46
73.13.....	12.89	1.18	1.17	.32	.32
96.0.....	4.90				
	.00				

It is noted that in a saturated atmosphere the dried Kieffer pears absorb large quantities of water. The dry material of the ripened fruit absorbed 68 percent of its weight of water, or enough to make its moisture content 40.5 percent. With lower humidities the amount of water absorbed becomes less as the humidity of the atmosphere becomes less.

It is noted that the difference in behavior in atmospheres of different humidities of the ripened and the unripened material is quite small and from a practical standpoint appears unimportant.

This entire series of tests was not repeated, but the tests for humidities of 94.2 and 100 percent were repeated several times with different lots of dried material. The quantities of water absorbed in the repeated tests were frequently considerably higher than in the series for which data have been given. In one case the material absorbed approximately 100 percent of water, or enough to make the moisture content 50 percent. This was thought to be due to differences in the original raw materials, but there was also some variation in the temperature of the room containing the storage chambers, which may have been partly responsible for the variation. There was a tendency at these high humidities for the material to weep during handling in weighing, and it was not always certain that some loss did not occur in this way.

In examining the moist and the dry material it was apparent that swelling occurred as water was absorbed. No measurements of the swelling were made, but, judging from the shrinkage in drying, it would be expected that the amount of swelling would be almost exactly equal to the volume of water absorbed.

The ripened material that had been stored in saturated air or in air having 94.2 percent relative humidity was quite soft and had very little tendency to regain its shape after being deformed by compression. It was very sticky, and the pieces would adhere when pressed together and might be squeezed into a solid ball. The sirupy material would stick to the hands, but no liquid could be squeezed out. The unripened material behaved similarly, but was perhaps a little less sticky and a little less plastic, or had a little less tendency to remain deformed after compression.

The material stored in air of 83.27-percent relative humidity behaved in somewhat the same way, appearing to be a little less soft and sticky.

The lots in air of 70.82-percent relative humidity were distinctly less soft but were still soft with little elasticity, and the pieces would adhere when pressed together tightly with the hands. If slightly compressed they would tend to separate to a certain extent, owing to the resiliency of the material. If an individual piece was bent it had a tendency to regain its former shape. The material was still quite sticky to the hands.

There were distinct differences between the ripened and the unripened fruit after storage at a relative humidity of 70.82 percent. The unripened fruit was more elastic and less sticky, but the pieces would adhere when tightly squeezed between the fingers. It appeared much drier than the ripened fruit, although the moisture content was very nearly the same, being 19.88 percent for the unripened fruit and 19.96 percent for the ripened.

In air of 62.28-percent humidity the ripened material showed considerable decrease in the tendency to stick together, and the pieces had a greater tendency to regain their former shape when bent. The pieces would still adhere if very tightly squeezed together with the hands. The unripened material also appeared less plastic and harder than in the higher humidities.

In air of 48.84-percent humidity the ripened material was pliable but tended to fall apart when a handful of the pieces were tightly squeezed together. The pieces could still be made to adhere if they were pressed tightly together for several minutes. The pieces did not break when bent but tended to regain their former shape.

The unripened material appeared hard and dry, but the pieces did not break when bent and tended to regain their former shape. It appeared distinctly drier than the ripened material; but, as in the above cases, this was not true, for the moisture content was nearly the same.

The ripened material in air of 33.3-percent relative humidity was only slightly pliable and would snap into two pieces when sharply bent. The pieces could not be made to stick together by pressing between the fingers, but were not dry enough to grind by hand in a mortar.

The unripened material was much more brittle, was tougher, harder, and seemed drier than the ripened fruit.

The ripened material in air of 21.44-percent relative humidity was hard and brittle. It could be ground coarsely in a mortar with a pestle but could scarcely be converted into a fine powder.

The unripened material seemed a little harder and drier than the ripened, but it could scarcely be made into a flour by grinding in a mortar with a pestle.

The ripened material in air of 12.89-percent relative humidity was hard and brittle and could be converted into a powder, but there was some tendency to stickiness. The unripened material seemed a little harder and more brittle but behaved in nearly the same way on grinding.

In air having 4.9-percent relative humidity or less, the material could be ground to a flour. Although the appearance of the ripened and unripened materials was quite different, they behaved in very nearly the same way on grinding.

From the results of these tests it may be concluded that the moisture content of the material, which is most desirable from the standpoint of handling and packing, is between 10 and 15 percent. The product with 10-percent moisture appears a little too dry, and that with 15 percent is a little too sticky. The changes in appearance in the product with 15-percent moisture in the course of 6 months or a year are not very important, because the color and flavor remain very good. The material is pliable and is readily refreshed. However, it is judged that if the material with 15-percent moisture is to be stored for a period longer than 1 year it will deteriorate noticeably in color and flavor unless air or oxygen is excluded. For long periods of storage with access of air the moisture should be reduced below 10 percent. It is also evident that the material should be placed in a package which excludes moisture, for no matter how dry the material may be at the finish of drying it will take up sufficient water from a moist atmosphere to cause the product to spoil completely.

PACKING THE DRIED PRODUCT

Experience accumulated in the course of work with the storage of dried Kieffer pears and other dried fruits leads to the belief that some practical suggestions in regard to their packing and preservation may be of considerable service to those inexperienced in the work.

The upper limit of moisture content that commercial evaporated apples may contain is fixed by Federal regulation at 24 percent, that of prunes at 25 percent, and that of peaches and apricots at 26 percent. The regulations do not prescribe an upper limit of moisture for evaporated pears, but the similarity of the product to dried apples would indicate that 24 percent should be taken as a limit for dried pears as packed. Commercial packages for dried fruit range from wooden boxes of 25- and 50-pound capacity to 5-pound, 2-pound, and 12-ounce paper cartons. The wooden boxes are lined with two or more layers of waxed paper, so folded as to protect the contents against entrance of dirt and insects and to reduce contact with air and access of moisture; the paper cartons may or may not have an inner lining, but are usually protected by an outer covering of waxed paper or cellophane designed to make them moisture and insect proof.

No matter what type of package is used, the material is packed into it under rather heavy pressure, which compresses the fruit into a compact block. This method of packing requires that the material have a moisture content sufficiently high to be quite elastic and rubbery, so that it may be strongly compressed without breaking or permanently distorting the individual pieces. As a commercial method this has the advantage not only of reducing the bulk of the material and the cost of containers but the compression of the material reduces access of air and moisture and consequently slows deterioration. It has the disadvantage that the material will take up water somewhat readily if exposed to a warm, moist atmosphere. This is prevented in the smaller cartons by sealing them into outer wrappings of moisture-proof paper, but with the larger boxes that must be held for prolonged periods it is necessary to resort to cold storage.

It would be advisable to dry material intended for home consumption to 10 percent or at most not more than 15-percent moisture content and to use tin cans having closely fitted slip tops or friction tops as storage containers. Heavy waxed paper or glassine bags are

also satisfactory if they can be closed tightly enough to exclude insects and moisture. Unwaxed paper or cloth bags are unsuitable, for the obvious reason that they do not exclude air and moisture and for the further reason that while such bags will exclude the Indian meal moth and other larger insect pests of dried fruit, some of the small beetles that sometimes attack dried fruit will cut through such paper or make their way through the meshes of the cloth. To be satisfactory, a container for dried fruit must be made of material that insects will not tunnel through, and it must be so made that it is practically airtight when closed.

RATE OF MOISTURE ABSORPTION

In order to obtain information on the rapidity of moisture absorption, the lots of material employed in the tests just described were weighed at short intervals during the first 2 or 3 weeks of the storage. The results have been calculated as percentage of water present in the material and as percentage of water absorbed. The results for the ripened material are given in table 4, and in figure 2 the moisture

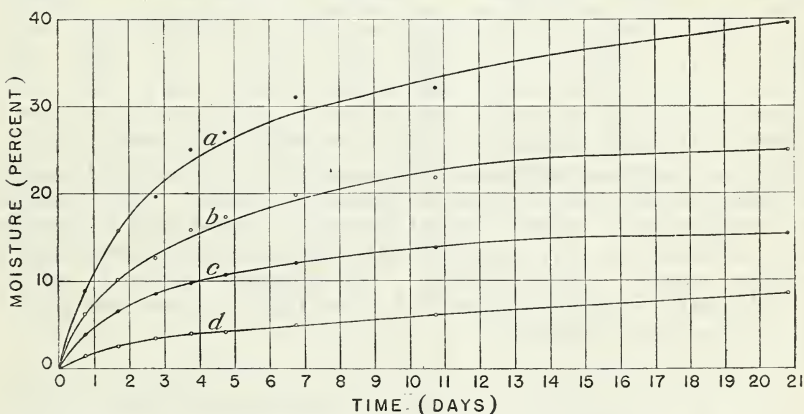


FIGURE 2.—Moisture content of dried Kieffer pears after storing in atmospheres of different relative humidity for different lengths of time. The material was stored at 20° C. and without any mechanical circulation of the air. The material was filled loosely into coarsely woven muslin bags: *a*, 100-percent relative humidity; *b*, 83.27-percent relative humidity; *c*, 62.28-percent relative humidity; *d*, 48.84-percent relative humidity.

percentage has been plotted against the time stored in the humidity chambers. It will be noted that the material absorbed water rather rapidly for the first few days and that the rate of absorption gradually decreased as equilibrium was approached. The greater part of the water was absorbed during the first 10 days, and at the end of 20 days equilibrium was very nearly established.

The differences in the quantities and rates of absorption in atmospheres of different humidity are very clearly shown in figure 3. Of course, the result of a test of this character will vary greatly with differences in temperature and degree of exposure of the fruit to the humid air. If the temperature had been higher the rate of moisture absorption would have been greater; if the fruit had been tightly packed instead of loosely placed in muslin bags the moisture absorption would have been slower. Likewise, if the air had been circulated rapidly the rate of absorption would have been increased. The size of the segments into which the fruit is sliced will also have an influence.

The extent to which temperature, air velocity, and other methods of exposure affect the rate of absorption was not studied, but some tests were made with fruit sliced into different-sized segments.

TABLE 4.—Rate of moisture absorption in initially moisture-free material in atmospheres of different humidity expressed as percentages of water absorbed and moisture present in the material

Relative humidity (percent)	0.76 day		1.70 days		2.76 days		3.75 days	
	Moisture	Water absorbed	Moisture	Water absorbed	Moisture	Water absorbed	Moisture	Water absorbed
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
100.....	8.90	9.77	15.94	18.9	19.57	24.3	24.90	31.6
83.27.....	6.3	6.7	10.08	11.2	12.71	14.5	15.85	17.4
62.28.....	3.98	4.1	6.64	7.1	8.54	9.3	9.80	10.8
48.84.....	1.56	1.58	2.44	2.5	3.33	3.44	4.00	4.16

Relative humidity (percent)	4.75 days		6.75 days		10.75 days		20.82 days	
	Moisture	Water absorbed	Moisture	Water absorbed	Moisture	Water absorbed	Moisture	Water absorbed
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
100.....	26.90	36.8	31.0	44.9	31.90	46.8	39.4	48.5
83.27.....	17.24	20.8	19.80	24.6	21.71	27.7	24.94	33.2
62.28.....	10.68	11.9	12.13	13.8	13.87	16.1	15.30	18.0
48.84.....	4.08	4.25	4.82	5.06	6.11	6.50	8.53	9.33

EFFECT OF SIZE OF SEGMENTS UPON MOISTURE ABSORPTION

The fruit for these tests was dried and stored at 100-percent relative humidity in the same manner as already described. The material was weighed at intervals during the storage period, and the results were calculated as percentage of water absorbed and percentage of moisture present in the material. The results are given in table 5 and illustrated in figure 3 where the percentage of moisture is plotted against the time of storage.

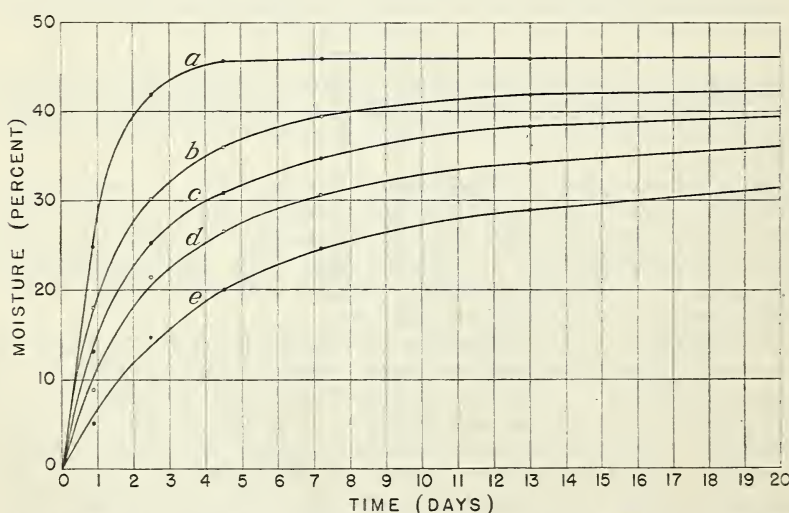


FIGURE 3.—Moisture content of dried Kieffer pears sliced into segments of different sizes and stored in an atmosphere of 100-percent relative humidity for different lengths of time. The air in the humidity chamber was not mechanically circulated, and the temperature of the storage was 20° C.: a, Fruit sliced into 32 segments; b, fruit sliced into 16 segments; c, fruit sliced into 8 segments; d, fruit sliced into 4 segments; e, fruit sliced into halves.

TABLE 5.—*Water absorbed by and water present in dried pears sliced into segments of different sizes after storage in an atmosphere of 100-percent relative humidity for various periods. The material was moisture-free at the beginning of the test*

Storage period (days)	Halves		Quarters		Eighths		Sixteenths		Thirty-seconds	
	Mois- ture	Water ab- sorbed	Mois- ture	Water ab- sorbed	Mois- ture	Water ab- sorbed	Mois- ture	Water ab- sorbed	Mois- ture	Water ab- sorbed
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
0.9.....	5.19	5.47	8.86	9.72	13.18	15.18	18.00	21.95	24.8	32.97
2.48.....	14.75	17.30	21.72	27.75	25.21	33.70	30.41	43.69	41.8	71.82
4.5.....	20.1	25.15	26.75	36.51	30.9	44.71	36.0	56.25	45.6	83.82
7.2.....	24.70	32.80	30.65	44.19	34.74	53.23	39.5	65.28	45.8	84.50
13.0.....	29.16	41.16	34.23	52.04	38.37	62.25	42.2	73.01	45.9	84.84
20.0.....	31.6	46.20	36.1	56.49	39.4	65.10	42.3	73.31	45.8	84.50

It is evident that the rate of absorption of moisture is tremendously increased in the fruit sliced into small-size segments before drying. At the end of 2½ days the fruit cut into thirty-seconds had a moisture content of 41.8 percent, whereas the halves had only 14.75 percent. The thirty-seconds had almost reached equilibrium at the end of 4.5 days, while the halves required approximately 35 days. From this it is evident that moisture penetrated the material comparatively slowly. It is also evident that the absorption of moisture from the air can be greatly lessened by storing the material in large masses with the pieces pressed tightly together, so that as little circulation of air as possible occurs between the pieces. This reduces the surface exposed to the air and minimizes the absorption of moisture. Of course, these results are comparative only, for, as already stated, the rate will vary with many other conditions.

REFRESHING THE MATERIAL

No matter how quickly a product may be dried or how satisfactory it may be in appearance, table quality, and other respects, its usefulness will be greatly limited if it cannot be conveniently prepared for the table. The first step necessary in this preparation is the addition of the proper amount of water. To add this water, it is customary to soak the material for a certain length of time in water of a certain temperature.

EFFECT OF TEMPERATURE UPON THE RATE OF ABSORPTION OF WATER IN SOAKING

For these tests, ripened fruits weighing 180 to 190 g were peeled, cored, and sliced into eight segments, then dried at 60° C. until very dry; the remainder of the water was removed by drying in a vacuum oven at 70°. This assured uniformity as to moisture content, made the weighings directly comparable, and simplified the calculations.

The material was soaked in large-mouthed Thermos bottles provided with stoppers through which thermometers extended. Baskets of such size that they could be rapidly and conveniently introduced or removed from the Thermos bottles for weighing were made from thin sheet aluminum, the walls being perforated to allow free circulation of liquid. One of these baskets held the material during the soaking. The Thermos bottles kept the temperature fairly close to that desired, but when variations of 2° occurred an adjustment was made by the addition of a little hot or cold liquid.

In order to submerge the material and to keep the individual pieces separated sufficiently to permit maximum absorption, it was necessary to use a rather large volume of water in proportion to the quantity of fruit. It was soon found that under these conditions so much sugar, acids, and other substances diffused out of the material as to leave some doubt whether the results represented accurately the amount of water absorbed. To partially correct this the soaking was done in an extract of the fruit itself.

To prepare this extract a quantity of dried fruit was soaked for 24 hours in enough water to make its moisture content 80 percent; the liquid was then squeezed out of the material and strained through muslin. This liquid contained approximately the concentration of sugars and acids that would be in the fruit after soaking if none diffused out. This method appeared very largely to correct for the diffusion of the solids out of the material during soaking in water, and it is believed that this concentration of solids in the water did not greatly affect the rate of water absorption.

The procedure may therefore be described as follows: The liquid prepared as described was brought approximately to the desired temperature and introduced into the Thermos bottle. The aluminum basket was then introduced and the temperature adjusted to exactly the desired point. The basket was removed from the liquid, drained 30 seconds, and weighed. The weighed material was placed in the basket, the pieces being kept as free from contact with one another as possible. The basket containing the fruit was then placed in the Thermos bottle, care being taken to see that all the fruit was submerged in the liquid. At the end of 5 or 10 minutes the basket was removed, allowed to drain 30 seconds, and weighed as quickly as possible. It was immediately returned to the Thermos bottle so that the fruit was out of the liquid not more than 1 to 1½ minutes. Subtracting the original weight of dry fruit and the basket from the total weight gives the weight of the water absorbed.

The material was weighed at approximate intervals until the end of 24 hours. After 4 hours the rate of absorption was much slower and the results are not recorded (table 6). The results were calculated in terms of moisture content of the fruit. The tests were repeated two or three times and the results averaged. The temperature of the soaking liquid varied by approximately 10° intervals from 0° to 93° C. The radial segments of one-eighth of a fruit were selected for uniformity and weighed approximately 2.3 g each. The results are given in table 6 and illustrated in figure 4.

It is noted that the moisture content increases very rapidly when the material is first put into the liquid. This increase is partially due to the layer of water held on the surface of the material, but even after making allowances for this the rate of absorption was very rapid. At 53° C. the moisture content of the fruit had risen from 0.0 to 39.4 percent at the end of 10 minutes; at the end of 55 minutes it was 56.3 percent. It appears that in soaking, water penetrates into the material more readily and rapidly than it diffuses out to the surface in drying. In drying, the osmotic forces and the forces of imbibition act to retard the passage of water to the surface, whereas in soaking they operate to hasten the penetration of water. Many other factors may also be concerned.

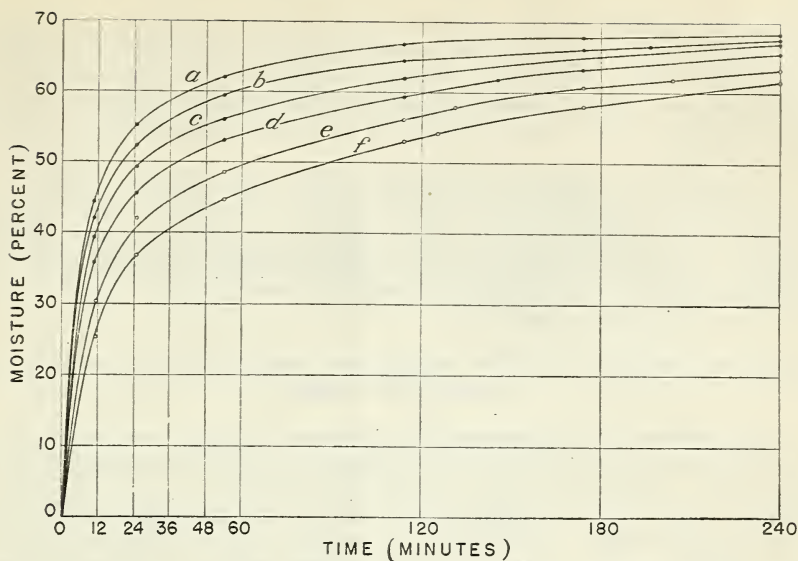


FIGURE 4.—Effect of temperature upon the rate of absorption of water by Kieffer pears, peeled, cored, and sliced into eight radial segments and dried to moisture-free condition: a, 93° C.; b, 73°; c, 53°; d, 33°; e, 13°; f, 0°.

TABLE 6.—Moisture content of dried Kieffer pears after soaking for different lengths of time at various temperatures. The fruit had been peeled and sliced into 8 radial segments and dried to moisture-free condition

Temperature of water during soaking (° C.)	Moisture content of the fruit after—						Temperature of water during soaking (° C.)	Moisture content of the fruit after—					
	10 min-utes	25 min-utes	55 min-utes	115 min-utes	175 min-utes	240 min-utes		10 min-utes	25 min-utes	55 min-utes	115 min-utes	175 min-utes	240 min-utes
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.		Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
0.....	25.4	36.9	44.6	53.5	58.0	61.5	53.....	39.4	49.1	56.3	62.2	64.9	66.7
13.....	30.43	42.0	49.0	56.3	60.7	63.2	63.....	40.8	50.6	57.8	63.5	66.2	67.5
23.....	33.6	44.0	50.9	57.9	62.1	64.2	73.....	42.1	52.2	59.7	64.7	66.2	67.5
33.....	35.9	45.7	52.8	59.4	63.2	65.5	83.....	43.1	53.7	60.6	65.9	67.0	68.4
43.....	37.8	47.4	54.6	60.9			93.....	44.1	55.3	62.1	67.0	67.9	68.4

The difference in the rate of absorption of water at high and at low temperatures is not so great as might have been expected when the difference in drying rates at high and at low temperatures is considered. At the end of 25 minutes the moisture content was 36.9 percent at 0° C., and 55.3 percent at 93°, while at the end of 4 hours it was 61.5 percent at 0° and 68.4 percent at 93°. It is evident that the rate of absorption of water is of a very different order from the loss of water in drying in that heat or energy must be supplied, in order to evaporate the water, whereas energy is not required in water absorption. On the contrary, considerable amounts of energy are liberated in the absorption of water by the material.

At the end of 24 hours the material had about reached equilibrium, so that no more water was absorbed. The moisture content of the material at this time ranged from 72 to 75 percent, hence was always a little lower than the moisture content of the fresh fruit before drying. Tests were also made upon the rate of absorption of water by the

unripened material. The results indicate that the differences in the rate of absorption were so small as to be unimportant from a practical standpoint. The unripened material appeared to absorb water a little faster than the ripened, and the total amount absorbed was a little greater. The moisture content of the material at the end was 73 to 75 percent.

As had been noted in these studies, the material swelled or increased in volume during the absorption of water. During the soaking the material did not quite regain its original volume before drying. It may be concluded from the shrinkage in drying that the swelling which occurs during soaking is almost exactly equal to the volume of the water absorbed.

RATE OF ABSORPTION OF WATER BY SEGMENTS OF FRUIT OF DIFFERENT SIZES

The material for these tests was prepared in the same manner as that for the tests on the effect of temperature, and the procedure was the same. Lots of fruit were subdivided into 2, 4, 8, 16, and 32 segments. The fruit was uniform and an effort was made to slice the fruit symmetrically. After drying, the segments were further selected for uniformity. No record was kept of the weights of the individual pieces, but the whole fruits weighed 175 to 185 g. The soaking was carried out at a temperature of 23° C., which remained practically constant throughout the tests. Each test was repeated three times and the results were averaged. The data are presented in table 7.

TABLE 7.—*Absorption of water by dried pears as affected by size of segment, showing percentage of moisture absorbed after soaking for various lengths of time at 23° C.*

Size of piece	10 min- utes	25 min- utes	55 min- utes	115 min- utes	175 min- utes	240 min- utes	450 min- utes
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Halves.....	17.2	22.5	28.2	36.1	39.5	43.5	53.3
Quarters.....	23.5	29.5	38.0	46.2	52.0	55.4	63.2
Eighths.....	33.6	44.0	50.9	57.9	62.1	64.2	69.0
Sixteenths.....	40.6	51.0	58.2	65.0	68.3	69.8	72.1
Thirty-seconds.....	58.1	65.6	69.2	71.7	72.8	74.0	74.0

It may be noted that there is a very great difference in the rate of absorption of water by segments of different sizes. At the end of 10 minutes halves had absorbed 17.2 percent of water, while the material that had been sliced into 32 segments acquired a moisture content of 58.1 percent. At the end of 1 hour and 55 minutes the one thirty-second segments had a moisture content of 71.7 percent, whereas the halves had only 36.1 percent.

The differences in rate and amount of absorption by pieces of different sizes for the first 8 hours of the soaking period are clearly shown in figure 5. The curves slope very sharply upward at first, gradually becoming horizontal toward the end of the soaking period. The effect of the size of the segment on the rate of absorption of water is very similar to that of the size of segment upon rate of loss of water in drying (10). In moisture-absorption tests the water must penetrate into the material; in the drying tests the water must diffuse out to the surface. However, it may again be noted that the time re-

quired to dry the material is much greater than the time necessary for it to absorb water to its capacity. As is well known to be the case with other materials, the time necessary to reach equilibrium when the material is submerged in water is much less than that required to reach equilibrium in the case of absorption of water from a humid atmosphere.

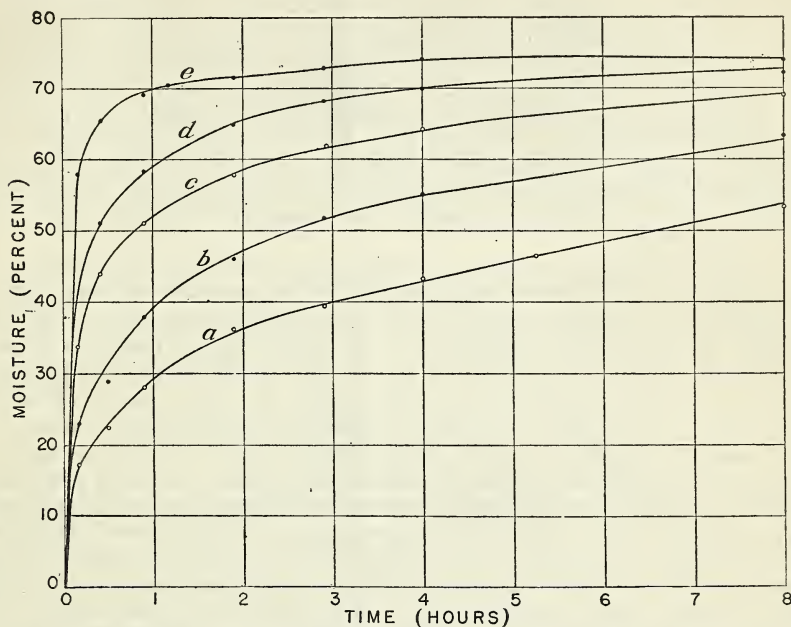


FIGURE 5.—Percentage of moisture content of dried Kieffer pears after soaking for different lengths of time: *a*, Halves; *b*, quarters; *c*, eighths; *d*, sixteenths; *e*, thirty-seconds.

It is obvious that the refreshing of the material is easily accomplished. With material sliced into eight or more segments it can be done almost as quickly as the fresh fruit can be peeled and cooked. Judging from the behavior of the material in these tests, the fruit sliced into eight segments can be more conveniently and attractively prepared for the table than that cut into segments of any other size.

EFFECT OF ADDING DIFFERENT QUANTITIES OF WATER FOR REFRESHING THE FRUIT

In refreshing any dried fruit it is advantageous to know the proper amount of water to add in order to give the product the characteristics most desirable for the particular form in which it is to be served on the table. It seemed reasonable to expect that an optimum moisture content would exist for the table product made of the dried Kieffer pear. A few tests were made to determine how the material behaved when different quantities of water were added.

For use in these tests the fruit was peeled, cored, sulphured, sliced into eight segments, dried at 60° C. until most of the water had been removed, and then completely dried in a vacuum oven over calcium oxide at 70°. For each test 150 g of the dried material was placed in a round-bottomed flask and enough water added to make the moisture

content the desired percentage. A reflux condenser was attached to the flask, which was then placed on a boiling water bath and heated for 4 hours. The flasks and contents were cooled overnight. Notes were then taken as to the quantity of water absorbed and the appearance of the material. The reflux condensers were removed and the contents of the flasks emptied into dishes and thoroughly stirred. An effort was made to determine the consistency of the intact pieces, but no very satisfactory method was devised; however, this suggested that by macerating the material as finely as possible in an ordinary food chopper the tests might be satisfactorily made. Any liquid not absorbed by the material was added and thoroughly mixed with the ground material. A consistency test was then made upon this material, using a consistometer originally devised for measuring the consistency of greases and petrolatum in accordance with the specifications of the American Society for Testing Materials for test D-217-27T (18).

In order to make satisfactory comparisons of the consistency of materials with widely varying moisture percentages it was necessary to construct a special cone suitable for obtaining readings upon substances of very thin consistency. A hollow cone that was found reasonably satisfactory for this purpose had walls made of thin sheet aluminum with one-half inch of the point or vertex made of steel. The outer face of the cone had a uniform slope from the vertex to the base, and made an angle of approximately 15° with the axis of the cone. Its altitude was approximately 8 cm. It was provided with an aluminum attachment or stem for holding the cone in position for its release. The cone and supporting stem had a total weight of 20 g and sank to a depth of approximately 64 mm in pure water. This cone proved to be well adapted for measuring the consistency of the products here under consideration. The tests were made at 20°C . In making the test, the material was placed in a suitable vessel, uniformly mixed, and placed upon the instrument. The cone was then lowered until the tip was just in contact with the surface of the material, and the pointer of the recording device was adjusted to zero. The cone was then released, allowed to fall for 5 seconds measured by a stop watch, and the distance read from the scale and recorded. Three to five readings were made on each sample and the results averaged (table 8).

TABLE 8.—Consistency of dried Kieffer pears after adding sufficient water to make the moisture content various percentages as measured by the distance to which the material is penetrated by a tall cone weighing 20 g; temperature of material, 20°C .

Moisture content (percent)	Depth of penetra- tion	Moisture content (percent)	Depth of penetra- tion	Moisture content (percent)	Depth of penetra- tion
	<i>Mm</i>		<i>Mm</i>		<i>Mm</i>
50-----	7.9	70-----	18.8	85-----	47.0
60-----	10.5	75-----	27.5	90-----	58.1
65-----	15.1	80-----	32.3		

It is noted that the cone penetrated 7.9 mm in the material with 50-percent moisture and 58.1 mm in the material with 90-percent moisture. It is noted that as the percentage of moisture changes from 80 to 90 there is a decided increase in the distance to which the cone

penetrates, indicating a very great change in the consistency. The increase in depth of penetration between 50- and 60-percent moisture is very much less. The results conform very well with the judgments as to the consistency formed after stirring the material or preparing it for table use.

The material to which sufficient water had been added to make the moisture content 50 percent absorbed all the added water; and, after grinding the product had a consistency equal to or greater than that of good apple butter. With 60-percent moisture, the product was as thick as average apple butter. In the material with sufficient water added to make the moisture content 75 percent practically all the water was absorbed in the heating and soaking and the ground product had a consistency equal to or heavier than that of apple sauce. The material with enough water added to make the moisture content 90 percent had a considerable quantity of unabsorbed water and was very fluid after grinding.

From these tests it is concluded that to have the most desirable consistency for use on the table the product should have a moisture content of approximately 75 percent. It is clear that a product of any desired consistency may be had by adding the proper amount of water.

USES OF DRIED KIEFFER PEARS

When the fruit of the Kieffer pear is ripened at the proper temperature, peeled, cored, properly sulphured, and dried under good drying conditions to a moisture content of 15 percent, the product obtained is attractive in appearance and pliable to the touch, sweet and palatable to the taste, and comparable in quality to the best dried Bartlett pears. The objectionable qualities are the presence of stone cells and a somewhat low sugar content, neither of which may be very serious. A product thus obtained may be prepared for the table in practically the same way as dried apples, peaches, raisins, and prunes.

No attempt has been made to work out any new methods of preparing the material for the table or of combining it with other materials to obtain appetizing dishes, although there are obviously various possibilities in these directions that would repay some attention. However, tests have been made upon the cooking quality of the dried material when prepared in most of the ways used in preparing evaporated apples, peaches, and prunes for the table. When stewed like peaches or prunes it appears advantageous to add sufficient sugar to make the concentration in the product as served about 20 to 30 percent. The product tends to darken somewhat in cooking, but is attractive in appearance and pleasing in flavor. Other tests have shown that the dried product can be made into satisfactory pies by methods similar to those used for making pies of dried peaches.

In these tests the product, if dried without previous ripening when cooked, was lacking in flavor, hard and woody in texture, and not attractive in appearance as compared with the ripened material.

The unpeeled product even in the case of ripened material appeared quite inferior to the peeled material.

DISCUSSION

The studies of Lutz, Culpepper, and Moon (12) have shown that the Kieffer pear is much improved in palatability when ripened at 60° F., and those of Moon and Culpepper (18) and Lutz, Culpepper, Moon,

and Myers (13) have shown that the quality of various products made from fruit so ripened is decidedly superior to that made from unripened fruit or from that ripened at either higher or lower temperatures. However, the fruit does not remain in good condition for a very long period after it has been ripened; changes continue to occur, and in a short time it begins to turn brown and loses distinctive flavor as a result of internal break-down. The fruit is much more susceptible to the attacks of fungi after ripening, so that once ripened it will soon perish unless it is preserved by some method. The life of the ripened fruit may be considerably extended by holding it at 32° F., but even with low-temperature storage the fruit cannot be kept in good edible condition for any extended period. Hence the usefulness of the fruit as a fresh product must be correspondingly limited. Where any considerable quantity of the fruit is produced some method of preservation must be employed. The possibilities for canning the fruit or of making preserves from it have been discussed elsewhere (13, 18). There may be many instances in which it is more convenient and more economical to dehydrate the material than to preserve it in other ways.

Because the fruit is grown over a very large portion of the eastern United States and therefore largely under rather humid conditions, it appears unlikely that sun-drying could be practiced to any extent in most of the area; also the fruit matures late in the season when the days are shorter and the temperature lower, which still further militates against successful employment of sun-drying. It seems, therefore, that drying by means of artificial heat is the only method which can be generally used for drying the fruit. Numerous writers have described drying equipment suitable for every condition and upon any scale from the simplest home-made cookstove or family driers to the large commercial dehydrators. This equipment cannot be detailed here, but a number of publications describing such equipment are included in the literature (1, 2, 3, 6, 7, 8, 16, 19, 20, 23), together with several papers of a more technical character dealing with the fundamental principles concerned in drying (5, 21, 22).

SUMMARY

Kieffer pears ripened at 60° F. for a sufficient length of time to give a pressure test of 2.5 to 3.5 pounds with the Magness pressure tester made a dried product much superior to that made from unripened fruit. When properly dried to a moisture content of 10 to 15 percent the ripened product was pliable, pale yellow in color, somewhat translucent, and when cooked made a table product that was mild and pleasing in flavor. The unripened product was hard, less flexible, opaque gray or white in appearance, and when cooked was tough and lacking in flavor.

Drying the material without peeling gave a product inferior in texture and flavor to that of the peeled fruit.

Fruit dried without sulphuring was brown and less attractive in appearance than that properly sulphured, but was superior in flavor when sampled after several months' storage unless the storage conditions had been poor. To sulphur properly the fruit sliced into halves required about 4 hours' exposure to the fumes of sulphur dioxide; and for fruit sliced into eight segments, about 2 to 3 hours. It required several times as long to sulphur the unpeeled fruit as that which had been peeled and cored.

The fruit may be dried when sliced in nearly any manner if the proper drying conditions are provided. Because of the increased rate of drying, the ease of sulphuring, and the convenience of preparing it for the table, slicing the fruit into eight radial segments appears to be advantageous.

The dried product of the Kieffer pear readily absorbs moisture from the air. In an approximately saturated atmosphere the dried product will absorb sufficient water to make its moisture content 40 to 50 percent. The equilibrium moisture of the material has been determined at 20° C. with various different humidities.

Regardless of the treatment received, the dried product deteriorates rapidly in moist air. The rate and the total amount of change vary directly with the relative humidity. For the 6-months period of storage the previously ripened material that had been sulphured prior to drying and placed in an atmosphere of 48.84-percent relative humidity was in fairly good condition, having a moisture content of 11.1 percent. It was concluded that if an extended storage period was necessary it would be advantageous to reduce the moisture content of the material below 10 percent. The material rapidly deteriorates in atmospheres above 70-percent relative humidity.

The dried product of the Kieffer pear is readily refreshed by soaking in water. The material absorbs sufficient water to make the moisture content 70 to 80 percent, or not quite so much as was originally present in the fresh fruit. The rate of absorption increases with increase in temperature, but not to the extent that might be expected from the difference in the rate of drying at the different temperatures.

The rate at which water is absorbed is very markedly increased by slicing the fruit into thin segments before drying. The results have been plotted and curves drawn showing the relationship of size of segment to the rate of water absorption.

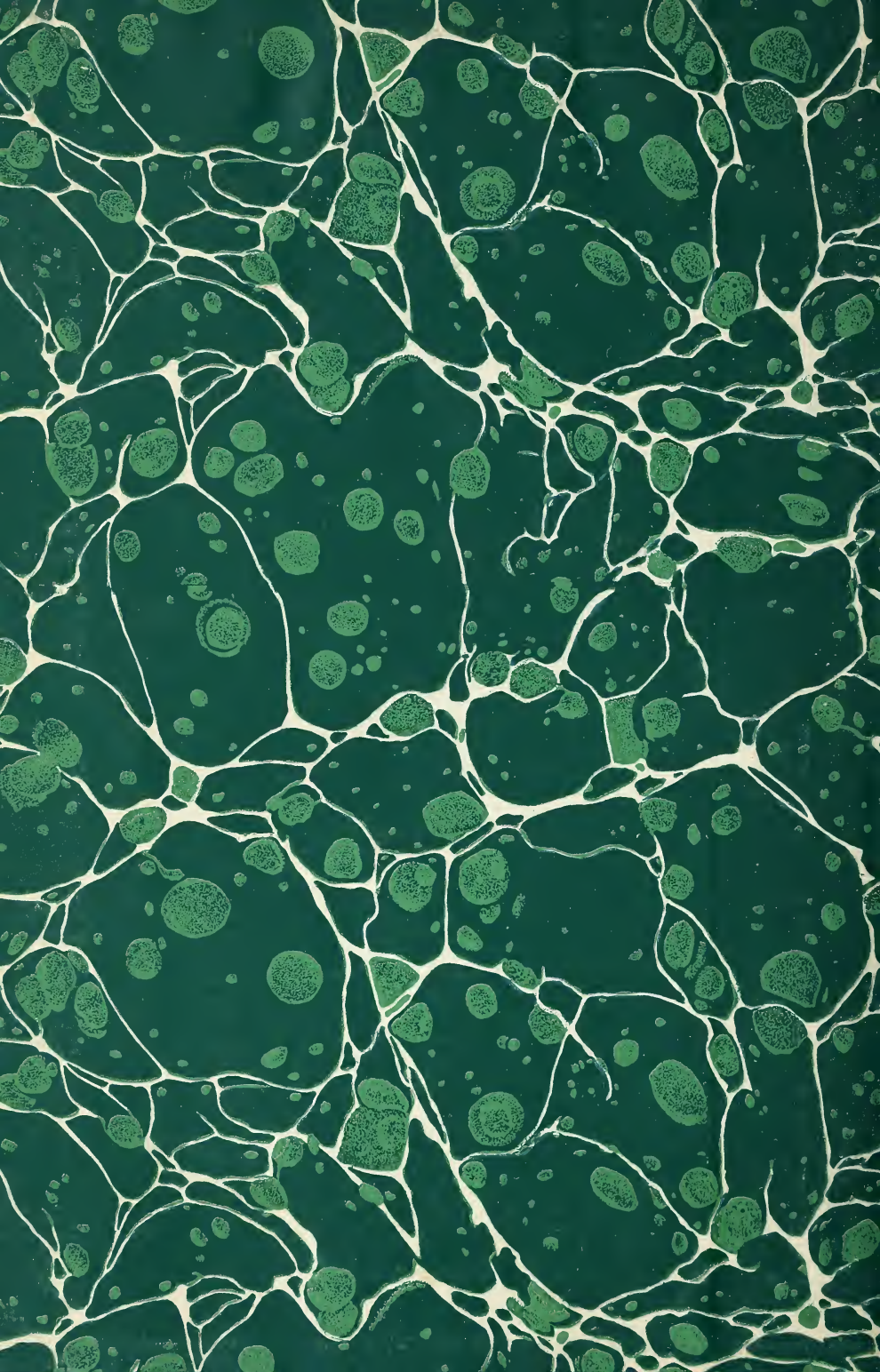
The addition of sufficient water to make the moisture content 50 to 60 percent gives a product which, when macerated, has a consistency about like that of apple butter. It has been concluded that about 75 to 80 percent of water is the proper amount to add to the material to give it the proper consistency for use as a sauce. The addition of sufficient water to make the moisture content 85 to 90 percent gives a product that is entirely too thin for use in most of the ways in which it might be prepared for the table.

The season at which the fruit matures is such that, in most of the area where the Kieffer pear is grown, it cannot be advantageously dried with solar heat alone. Drying equipment employing artificial heat will be necessary, except possibly in areas normally having very hot, dry weather during the late autumn months.

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